Technology Development Initiatives and Partnership Program
Request for Funding
FY2004

FHWA Strategic Goal Area:
Mobililty, Productivity

FLH Technology Strategy:
Advance new materials, design concepts, and innovative practices that could significantly improve durability, longevity, and reliability.

Project Title:
The Evaluation of the Dimethyl Sulfoxide (DMSO) Method for Determining Rock Quality

Problem Statement:
During the past 10-15 years, environmental restrictions and the increased cost of hauling rock have combined to reduce the number of material sources that are economically suitable for use in highway construction. The Western Federal Lands Highway Division (WFLHD) has used the twelve percent loss criterion of the Dimethyl Sulfoxide (DMSO) test for about 25 years to accept or reject material sources that contain swelling clays. DMSO penetrates the aggregate and interacts with the swelling component weakening the rock and leading to accelerated breakdown. It is believed the laboratory evidence of this test indicates the aggregate will rapidly degrade in surface applications and thereby reduces pavement life.

The objective of this technology initiative is to 1) evaluate the risk of increasing the maximum allowable limit of swelling clay from the 12 percent limit; 2) develop a precision statement; and 3) submit the test procedure for AASHTO review and adoption.

Background:
The investigation into the cause of the total failure of base and surface courses on the Nestucca River Access Road in the Oregon Coast Range in the late 1960's led to the discovery that the aggregates used to construct the project pavement contained swelling clays. Swelling of the clays when the aggregates became wet caused the aggregate to break apart and degrade quickly to gravelly silt and clay resulting in failure of the pavement. The recognition that swelling clay bearing aggregates were the cause of this and other pavement failures on Forest Service and BLM lands in the Pacific Northwest led WFLHD to develop a test to predict aggregate degradation potential. This test was the DMSO test, which has been used by the WFLHD since 1978.

Prior to the development of the DMSO test, a microscopic examination technique known as "optical petrography" was used to determine the amount of swelling clay in rock. That procedure relied on the staining of swelling clays with benzidine dye to a bright blue-green color and the subsequent determination and quantification of the swelling clays under a petrographic microscope. The technique provided reasonably accurate information about the swelling clay content of rock but was time-consuming and required the knowledge of a trained optical petrographer.

Although a formal, written petrographic test method and acceptance criteria was not developed by WFLHD, it was generally accepted that rock containing more than 10 percent swelling clay by volume had the potential to degrade in road service and was deemed unsuitable for use in the manufacture of roadway aggregates.

The availability of benzidine dye in the United States was lost in about 1980 following its listing by the FDA as a known carcinogen. With the loss of benzidine, the ability to determine the swelling clay content of rock by optical petrography was lost, and the DMSO test became the sole means of assessing the degradation potential of rock for aggregate production. The weight loss in the DMSO test that was initially established as the criterion for acceptance or rejection of an aggregate source was 20 percent. Subsequent observations of failures that had occurred in pavements constructed with rock having DMSO losses in the range of 12 to 20 percent lead to lowering of the acceptance criterion to a maximum loss of 12 percent, which is the current WFLHD standard.

Petrographic examination of rock thin sections for the presence of swelling clays is a "direct" method of the determination of swelling clays. The DMSO test, however, is an "indirect" method of testing. It does not identify or quantify swelling clays; instead, it measures the amount of degradation of a rock caused by the presence of swelling clays. During the 1980's, three research investigations examined the relationship between swelling clay content of rock and DMSO loss. Those studies verified the assumption that DMSO reacts with swelling clays and could be used as a test method to predict the potential for rock to degrade. The studies also concluded that the presence of certain other minerals such as calcite and certain zeolite minerals in a rock containing swelling clay could cause DMSO to "over-react" with the swelling clays. To minimize the potential for obtaining "false readings" in rock containing calcite or zeolite, the researchers proposed additional petrographic methods for use with the DMSO test in rocks containing those minerals. However, because it was felt that the potential to obtain significantly false readings was very low, and because of the desire to have a single, rapid, easily performed test with which to evaluate rock, the FHWA did not adopt the use of supplemental petrographic tests.

Benefits:
The FHWA has used the DMSO test, by itself, for 25 years to predict the potential for rock to degrade and to limit the use of potentially degrading rock on its highway projects. If the allowable DMSO loss could be increased without affecting the design life of asphalt pavements, a greater number of aggregate sources would become acceptable for use with a potential reduction in cost.

Successful completion of this initiative will provide a validated, statistically based laboratory procedure, a maximum threshold value for loss, and a test method recognized by AASHTO.

Scope:
The project would begin by examining WFLHD laboratory records to identify 15 quarries (three each in western Idaho, eastern Washington, eastern Oregon, northwestern Oregon, and southwestern Oregon) having DMSO test values distributed approximately equally between 0 to 50 percent DMSO loss. Samples would be obtained from each quarry and shipped to the Vancouver Materials Testing Laboratory.

Laboratory testing would begin by crushing each quarry sample to the required test gradation. Standard prequalification tests including Coarse and Fine Durability, LA Abrasion, Sodium Sulfate Soundness, and Specific Gravity would be performed on each quarry sample to ensure samples meet minimum quality standards. Since percent loss in the DMSO test is directly related to the swelling clay content of the rock, the quarry samples would also be analyzed by X-Ray Diffraction ("XRD") to determine the amount of swelling clay in the rock from each quarry. The determination of the percentage of swelling clay will establish baseline information relating DMSO loss directly to swelling clay content by X-ray Diffraction, which has not previously been done.

Samples will then be subjected to the DMSO test following the WFLHD procedure. The DMSO test will be repeated on each quarry sample to provide complete and sufficient data to determine the within laboratory reproducibility and the statistical soundness of the test procedure. A within laboratory precision statement will be developed from the data using ASTM C 670 and ASTM C 802.

In the second phase of the study asphalt concrete briquettes would be prepared from aggregates with a range DMSO loss. The briquettes would be subject to rut testing in an Asphalt Pavement Analyzer ("APA") in both wet and dry conditions. The data obtained from the APA would be compared to the DMSO losses of the aggregates to establish a relationship between percent DMSO loss and rut depth. This data would be used to validate a maximum DMSO threshold value.

A final report that documents the test procedure, methods of data analysis, and results and conclusions of the study and presents any recommendations that result from the study will be the final deliverable. The DMSO test method will be reformatted according to AASHTO guidelines and included in the final report as stand-alone appendix. The test method will include a within laboratory precision statement based on the data collected.

Deployment Method:
The deliverables of this initiative are the refined test methodology, including correlation tables, precision statements, background information, and supporting guidance. Successful implementation of this methodology will depend on 1) a thorough final report, 2) presentations to interested user groups to discuss the test method and answer questions, and 3) submission of the test procedure to the AASHTO Subcommittee on Materials for inclusion in the Standard Specifications for Transportation Materials and Methods of Sampling and Testing.

The audience beyond Federal Lands for this methodology includes practitioners who design and maintain roadways, such as DOT engineers, government agencies, and engineering consultants.

The Technology Deployment team can use a variety of communication "tools" - such as technical briefs, presentations, and the Federal Lands Web site - to acquaint the potential user groups. For example, educational outreach to DOT engineers could occur at the yearly TRB meeting, where a presentation could be made. Articles highlighting the test method can be developed for one or more periodicals such as Public Roads or the Research and Technology Transporter.

Estimated Costs:
WFLHD will be responsible for data collection, fieldwork, data analysis, final report, submission of test procedure to AASHTO, and deployment of the technology.
The estimated cost of this proposal including deployment is $145,000.

Duration:
For purposes of the study proposal, the following time requirements are estimated.

Laboratory Study and Final Report	July 2005
Submission of Test Method to AASHTO	Fall 2005
Presentation at TRB	Spring 2006

Champion(s):
A Technical Working Team comprised of the following WFLHD personnel is proposed:
Dave Lofgren, WFLHD Engineering Geologist, Champion
Project management, quarry identification and sampling, data analysis, report writing
Brad Neitzke, WFLHD Materials Engineer
Laboratory test procedures, quarry sampling, data analysis, AAASHTO submission
Bruce Wasill, WFLHD Quality Assurance Engineer
Laboratory test procedures, test repeatability, statistical analysis of data
Amit Armstrong, WFLHD Technology Deployment Coordinator
Review, deployment